

A Data Interchange Standard for Clinical Neurophysiology

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A Standard Specification for Transferring Digital Neurophysiological Data Between Independent Computer Systems (Designation E 1467-92) has been developed. The specification defines a common representation of all of the data associated with a complete clinical study, including digitized neurophysiological waveforms, textual annotations and interpretive reports. Patterned after existing, related healthcare data interchange standards, it will facilitate data interchange between neurophysiological instruments, computer systems within the neurophysiology laboratory, other information systems in the hospital, and outside healthcare facilities or research laboratories.

INTRODUCTION

The Clinical Neurophysiology Laboratory has many different instruments for performing neurophysiological studies such as electroencephalography (EEG), evoked potentials (EP), electromyography (EMG) and nerve conduction studies (NCS), polysomnography (PSG), and magnetoencephalography (MEG). Modern instruments use digital computer technology to acquire, display, analyze, and store these electrophysiological waveforms (Figure 1). As these instruments mature, the ability to transfer data between systems specialized for different tasks, manufactured by different vendors, or from successive generations of technology will permit integration of the neurophysiology laboratory [1].

Automation of the process of acquiring and analyzing large quantities of waveform data, in some cases hundreds of megabytes per day, depends upon a common representation of the data if the data is to be shared between systems. This significantly simplifies the task of development (therefore reducing the cost) of custom software interfaces between each pair of communicating systems, as any system needs only a facility to read and write the standard interchange format.

HISTORY

The requirements for a standard for Clinical Neurophysiology were established in June of 1990 at the Second International Cleveland Clinic Epilepsy Symposium [2]. ASTM Subcommittee E31.16 on Interchange of Electrophysiological Waveforms and Signals was formed in September of 1990 to develop this standard, a cooperative undertaking representing clinical, academic, and commercial (vendor) interests. Several medical specialty societies have officially contributed to this effort, including the American Electroencephalographic Society, the American Association of Electrodiagnostic Medicine, American Sleep Disorders Association, and the International Society on Brain Electromagnetic Topography. The Standard Specification for Transferring Digital Neurophysiological Data Between Independent Computer Systems (ASTM Designation: E 1467-92) [3] was officially approved in March of 1992.

SCOPE OF THE STANDARD

The standard defines a portable digital representation of a complete neurophysiological study; it encompasses all phases of a study in a clinical environment, from ordering through final reporting and archiving. The standard covers most all classes of neurophysiological signals, including EEG, EP, EMG, NCS, PSG, and MEG. A format is defined for encoding digitized multichannel time-series waveform samples, plus all of the data needed to deformat and label the waveforms, textual annotations of the study by the technologists, physician or computer generated analyses of the waveforms, and final interpretive reports. Additionally, coding systems for much of the annotative data are defined to facilitate machine processing and extraction of information for display, reporting, or incorporation into a clinical database or computerized patient record. While the standard



Figure 1. Typical EEG Waveform [Recording]

directly addresses neurophysiological studies, the mechanisms are designed to be general and extensible, so special studies that incorporate other types of waveforms, such as electrocardiograms (ECG), hemodynamic parameters, intracranial pressures, etc. can use the standard as well. Prolonged studies or continuous monitoring can be accommodated as well as short, time-limited data acquisition. In addition, there are provisions for two-way communication between computer systems, which can be utilized, for example, for control of instrumentation or automatic ordering and reporting of clinical studies.

PORTABLE DATA INTERCHANGE

The primary goal of this standard was to facilitate transfer of data between computer systems independent of hardware architecture, operating system, or programming language, and across a variety of communications or storage media (e.g. local area networks, asynchronous serial interfaces, magtape, floppy disk, optical disk, etc.) [4]. Therefore, portability of the data files is of greatest importance. Efficiency, in terms of file size, data transmission speed, or formatting/deformatting time is of secondary importance, though not negligible for large volumes of continuously acquired waveform data. The standard does not constrain the internal architecture of any particular instrument or computer system; it defines how all such systems could export and import data, but leaves it up to the designers of a given system to decide whether or not a proprietary internal architecture is justified on the basis of performance,

features, or cost.

In order to achieve maximum portability of the waveform data, the standard specifies conversion of the binary data samples to decimal ASCII (7-bit) as the default encoding scheme. This permits transmission through the vast majority of hardware and software interfaces with a minimum of complexity. The penalty in terms of file size expansion is not as large as it might appear. An integer value in a two-byte sample could take four or five ASCII digits to encode, plus sign and delimiter, totaling up to seven bytes instead of two. However, real EEG data tends to fluctuate near the zero baseline, with relatively low amplitude for the majority of the study. It has been shown that typical EEG recordings expand to only 1.7 times the size of the original binary file; both the binary and ASCII files can later be compressed to approximately 0.7 times the size of the original binary file.[5] (Note that data compression schemes are explicitly NOT specified in the standard; the formatted data file can be compressed by standalone compression programs or by data communications or storage hardware when required and appropriate.) As communications and storage hardware continue to mature, this impact will become even less significant.

DATA FORMAT

The standard was patterned very closely after ASTM E1238-92, Standard Specification for Transferring Clinical Observations Between Independent Computer Systems [6]. E1238 is an

accepted standard for the transmission of test results from clinical laboratory systems (e.g. blood chemistry, cultures, etc.). Neurophysiological systems were considered to be analogous, with waveforms simply another type of "result". The already accepted and tested means of identifying and encoding data about patients, providers, orders, etc. were adopted from E1238. Within that structure, E1467 specifies extensions and enhancements for waveforms and their acquisition parameters, specific mechanisms and coding tables for associated annotations and reports, as well as mechanisms to support real-time operation.¹

Data files are stream-oriented, so that a single file contains all of the waveform data, descriptive information, textual annotations, and analyses and interpretation of the neurophysiological study. This single data file is analogous to a conventional analog paper EEG recording, with the technologist's annotations written on the stripchart, and the physician's interpretive report stapled to the stack of paper. All data needed to make sense of any portion of the waveform recording is always in close proximity; this is especially important for realtime communication or in continuous monitoring. Nevertheless, for efficiency, an instrument or computer system may choose to maintain state information so that redundant transmission of descriptive data can be minimized.

Data samples may be organized in either a channel-multiplexed or channel-demultiplexed format. The data stream may be segmented into 220-character blocks to meet the limitations of some common serial interface drivers. The textual descriptive and annotative information is embedded in the waveform data stream. Annotative data may entirely unformatted free text for screen displays and printing on reports, or may be encoded to facilitate machine processing, e.g. allowing counting or statistical analysis, dynamic formatting of reports, or extraction of data elements for incorporation

¹ The central philosophy to adopt the structure and formatting specified by E1238 was followed wherever possible to provide uniformity within the healthcare environment, in the same way that E1238 and HL-7 [7] are similar. For example, the written report of a study acquired on a Neurophysiology Laboratory instrument should be able to be distributed throughout the hospital, using essentially the same information systems and interfaces as the Clinical Laboratory, Radiology Department, etc..

into a database. For encoded annotations, the "universal" codes may be supplemented or replaced by local codes, or by new code tables that may be incorporated into future revisions of the standard. The code tables specified are designed so that data files formatted using encoded annotations will be interpretable if printed as free text by a deformatter that does not support encoded annotations. Annotations may be very simple, for example human-generated markers such as "patient moved"; or, they may be very complex, such as the parameters of a waveform feature (e.g. an EEG spike) detected automatically by a signal processing algorithm. (See Figure 2 for an example of a formatted interchange file)

IMPLEMENTATION

The standard may be implemented in a range of levels of complexity, or even in subsets appropriate to a particular instrument or task. A very simple implementation may handle only waveforms and the minimal descriptive information required to reformat the data stream. Another simple subset to implement would be the formatting of an interpretive report for transmission to a hospital information system for display of study results throughout the hospital. An implementation that formats waveforms and embedded annotations may initially treat all annotations as uninterpreted free text, and evolve to machine processing of encoded annotations when and where needed. A diagnostic instrument may provide only batch-oriented output of the data that it collected, or a laboratory computer system may implement two-way communication to control an instrument or interact with a hospital information system. Another important feature of the standard is flexibility to make implementation-specific or site-specific extensions to accommodate special requirements or features. Clinical encoding schemes specified may be supplemented or superseded to accommodate individual laboratory conventions without producing unreadable files.

This standard has been developed at an opportune time, when proprietary implementations do not exist, yet recognition of the need for this functionality is growing. As implementations evolve, cooperation among developers will lead to a better understanding of this data representation and guide future revisions of the standard.

H|^~\&|19264|34X96ABE59YW|NEULAB (Sunnyville Neurophysiology Lab)|<CR>
A|102 W Main Street^Mai
1 Stop 29B^Sunnyville^IN^66666|ORU^R01|(555)444-3333|<CR>
A|TCP/IP|NEURO (Sunnyville Neurologic Clinic)|Example|P|E.1|19900324101215<CR>
P|1|4567890&1&M10|4567890&1&M10|3-777-222|Doe^John^Q^Jr^Mr|Deere|19300202|<CR>
A|M|W|511 Third Avenue^Apt 2^Hometown^IN^66667||445-1111Cday~445-2222Cevening|<CR>
A|32975^Smith&John&P&III&Dr&MD^UPIN|||160^cm|60^kg|401.9^Hypertension^I9C|<CR>
A|Propranolol~Diazepam|Last meal 12 hrs ago||Right|19900214|IP|Psych||C|<CR>
A|M|BP|English|PSY|19900214<CR>
OBR|1|5678^NEURO|1234^EEG|95816^EEG recording|R|19900323095216|<CR>
A|19900324081216|19900324085142|||N|^dementia|^60year old male with 3 month hx<CR>
A|of myoclonus, cognitive decline, and memory loss||32975^Smith&John&P&III&Dr&MD|<CR>
A|444-3555|||19900324101017|214.50|EN|F|||WHL|97235^Berger&Hans&&&Dr|<CR>
A|27593^Jones&Mary&S&&Dr&MD|^Sullivan&Joyce&D&&Ms|^Quincy&Susan&R&&Ms<CR>
OBX|1|CM|95816&DST^EEG recording|1|T-10147&<CR>
A|external occipital protuberance (inion)^T-12171&frontonasal suture (nasion)^36.5~<CR>
A|T-Y0171-LFT&left preauricular area^T-Y0171-RGT&right preauricular area^37<CR>
OBX|2|CM|95816&MTG|1|1&LR-21.1 (A1/2)^21<CR>
OBX|3|CM|95816&ELC|1|1&Fp1^T-Y0100&head^DP&Au&0.6^90&TH^108&PH~<CR>
A|2&Fp2^^^90&TH^72&PH~3&F3^^^64&TH^129.1&PH~4&F4^^^64&TH^<CR>
A|50.9&PH~5&C3^^^45&TH^180&PH~6&C4^^^45&TH^0&PH~7&P3^^^64&TH^<CR>
A|230.9&PH~8&P4^^^64&TH^309.1&PH~9&O1^^^90&TH^252&PH~10&O2^^^<CR>
A|90&TH^288&PH~11&F7^^^90&TH^144&PH~12&F8^^^90&TH^36&PH~<CR>
A|13&T3^^^90&TH^180&PH~14&T4^^^90&TH^0&PH~15&T5^^^90&TH^216&PH~<CR>
A|16&T6^^^90&TH^324&PH~17&Fpz^^^90&TH^90&PH~18&Fz^^^45&TH^<CR>
A|90&PH~19&Cz^^^0&TH^0&PH~20&Pz^^^45&TH^270&PH~21&Oz^^^90&TH^<CR>
A|270&PH~22&A1^^^120&TH^180&PH~23&A2^^^120&TH^0&PH~24&Av^^DERIV^<CR>
A|0.5&A1^0.5&A2<CR>
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OBX|24|CM|95816&CHN^EEG recording|3|1^Fp1&Av^0.5&uv^1.032&0^^-2048&2047^<CR>
A|BP&ANA&1&6&70&6~2^Fp2&Av^^1.015&0~3^F3&Av^^0.983&0~4^F4&Av^^<CR>
A|1.005&0~5^C3&Av^^0.964&1~6^C4&Av^^0.993&0~7^P3&Av^^0.989&0~8^P4&Av^^<CR>
A|1.013&0~9^O1&Av^^1.106&0~10^O2&Av^^0.992&2~11^F7&Av^^<CR>
A|0.987&0~12^F8&Av^^1.002&0~13^T3&Av^^1.076&-1~14^T4&Av^^<CR>
A|1.112&0~15^T5&Av^^0.988&0~16^T6&Av^^1.087&0~17^Fpz&Av^^<CR>
A|0.992&0~18^Fz&Av^^1.135&0~19^Cz&Av^^0.988&0~20^Pz&Av^^<CR>
A|1.103&0~21^Oz&Av^^0.998&0<CR>
OBX|25|CM|95816.0101&TIM^EEG recording, with standard conditions while awake with<CR>
A|eyes closed|3|19900324081237.525^0.005^^DNC<CR>
OBX|26|TX|95816.0101&TCM|4|Awake<CR>
OBX|27|TX|95816.0101&TCM|5|Eyes closed<CR>
OBX|28|CM|95816.0101&WAV|7|39^543^-104^23^418^-35^260^864^-920^<CR>
A|450^80^460^-480^88^670^202^-90^-540^60^10^-680~601^36^-204^<CR>
A|605^440^-20^170^340^-424^-40^-30^28^380^-850^320^760^700^<CR>
A|-60^68^78^630~-280^120^90^-7^284^382^-96^-445^864^118^<CR>
A|-642^94^27^89^178^-683^58^-173^-53^664^510~-78^155^780^90^<CR>
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.
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Figure 2. Example E1467-92 Formatted Interchange File [8]

OBX|2975|TX|95816&MDT|1| The present recording shows nonspecific generalized <CR>
A|irregularities of cerebral function consisting of slowing of the background, as <CR>
A|seen on the previous EEG performed 2/15/90. In addition, there are now <CR>
A|periodic generalized sharp waves of the type seen in Creutzfeldt-Jakob disease, <CR>
A|or in certain types of metabolic disorders such as post-anoxic encephalopathy, <CR>
A|hypothyroidism, or baclofen or lithium intoxication. These were correlated with <CR>
A|the subject's myoclonic jerks at times. ~ ~ If clinically indicated, a follow-up <CR>
A|examination in 1 month could be used for further evaluation. <CR>
OBX|2976|CE|95816&DEV|1|^Grass model 8 (21 channels) with PC-based computer <CR>
OBX|2977|CE|95816&CNP|1|95816.2100^EEG recording, during hyperventilation <CR>
OBX|2978|CE|95816&CNP|2|95816.3100^EEG recording, during photic stimulation <CR>
OBX|2979|CE|95816&ANT|1|0017^Generalized, maximal anterior head region^ <CR>
A|AS4&DIST <CR>
OBX|2980|CE|95816&IMP|1|7156^Very frequent periodic sharp waves^ <CR>
A|AS4&EEGD|||A~W <CR>
OBX|2981|CE|95816&ANT|2|0010^Generalized^AS4&DIST <CR>
OBX|2982|CE|95816&IMP|2|910214^Continuous low-amplitude theta activity^ <CR>
A|AS4&EEGD|||A~W <CR>
OBX|2983|CE|95816.2100&IMP^EEG recording, during hyperventilation|3| <CR>
A|8^No activation^AS4&EEGD <CR>
OBX|2984|CE|95816.3100&IMP^EEG recording, during photic stimulation|4| <CR>
A|8^No activation^AS4&EEGD <CR>
OBX|2985|CE|95816&REC^EEG recording|1|95816^EEG recording: 30 days <CR>
.
.
.
L|1||3|819723|19264 <CR>

Figure 2. (continued)

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- [8] Example excerpted from ASTM E1467-92, Table X3.1 (see reference 3).